A sensor arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump includes a control piston operable to control an angle of the swashplate relative to the variable displacement pump; a position marker arranged on the control piston; and a sensor arranged along the control piston to detect a movement of the position marker.
SWASHPLATE POSITION SENSOR ARRANGEMENT

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD

[0002] The invention is related to a sensor arrangement for确定ing an actual swashplate angle of a swashplate.

BACKGROUND

[0003] Variable displacement hydraulic pumps, such as axial piston variable displacement pumps, are widely used in hydraulic systems to provide pressurized hydraulic fluid for various applications. For example, hydraulic earthworking and construction machines, e.g., excavators, bulldozers, loaders, and the like, rely heavily on hydraulic systems to operate, and hence often use variable displacement hydraulic pumps to provide the needed pressurized fluid. These pumps are driven by a mechanical shaft, for example by an engine, and the discharge flow rate, and hence the pressure, is regulated by controlling the angle of a swashplate pivotally mounted to the pump. Operation of the pump, however, is subject to variations in pressure and flow output caused by variations in load requirements. It is desirable to maintain the discharge flow rate of the pumps in a consistent manner so that operation of the hydraulic systems is well behaved and predictable. Therefore, attempts have been made to set up a control process including a step of sensing the swash plate position by a rotative sensor sensing the swivelling angle of the swash plate that is related to the pump stroke and hence the discharge flow rate.

[0004] In U.S. Pat. No. 6,623,247 B2, a method and apparatus for controlling a variable displacement hydraulic pump having a swashplate pivotally attached to the pump is disclosed. The method and apparatus includes determining a desired swashplate angle as a function of a power limit of the pump, determining an actual swashplate angle, determining a value of discharge pressure of the pump, moving a servo valve spool to a desired position as a function of the desired swashplate angle, the actual swashplate angle and the discharge pressure, and responsively moving the swashplate to the desired swashplate angle position. A means for determining the actual swashplate angle is adapted to determine the angle of the swashplate using a swashplate angle sensor, for example, a resolver or a strain gauge.

SUMMARY

[0005] An aspect of the invention provides a sensor arrangement arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, the arrangement comprising: a control piston operable to control an angle of the swashplate relative to the variable displacement pump; a position marker arranged on the control piston; and a sensor arranged along the control piston to detect a movement of the position marker.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention will be described in even greater detail below based on the exemplary figures. The invention is not limited to the exemplary embodiments. All features described and/or illustrated herein can be used alone or combined in different combinations in embodiments of the invention. The features and advantages of various embodiments of the present invention will become apparent by reading the following detailed description with reference to the attached drawings which illustrate the following:

[0007] FIG. 1 shows a sectional view of a variable displacement hydraulic pump with a rotative sensor according to the state of the art;

[0008] FIG. 2 shows a sectional view of a variable displacement hydraulic pump with an embodiment of the sensor arrangement according to the invention; and

[0009] FIG. 3 shows a schematic illustration of the sensor arrangement in detail.

DETAILED DESCRIPTION

[0010] In the prior art, a problem is incurred by the control loop including a proportional valve being actuated by a controller, the proportional valve moving a control piston, the control piston swivelling the swashplate via a position member and, finally, sensing the swivelling angle of the swash plate as a feedback signal to the controller, because the number of clearances in the control loop may cause unstable operation of the control process.

[0011] An aspect of the present invention is directed to providing a more stable control of a variable displacement hydraulic pump.

[0012] An aspect of invention is related to a sensor arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, to a measurement method for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, to a controller for controlling the actuation of a control piston of a variable displacement hydraulic pump and to a variable displacement hydraulic pump.

[0013] The sensor arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, according to the invention, comprises a control piston operable to control an angle of the swashplate relative to the pump a position marker arranged on the control piston and a sensor arranged along the control piston to detect a movement of the position marker. By using such a sensor arrangement, all clearances in the control loop are advantageously eliminated. This allows for a more stable pump control compared to the existing design.

[0014] According to a preferred embodiment, the sensor is adapted to detect the movement of the position marker in a contactless manner. The contactless sensor arrangement advantageously provides a completely wear-free design.

[0015] Furthermore preferred, the sensor is arranged generally parallel or coaxially to a direction of movement of the control piston. In particular, the sensor is a linear magnetostrictive position sensor and the position marker is a magnet.
The measurement method for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, according to the invention, wherein a control piston is operable to control an angle of the swashplate relative to the pump, comprises the steps of detecting a position of a position marker arranged on the control piston by a sensor arranged along the control piston and determining a linear translation of the control piston from a shift of the position marker relative to the sensor. In particular, the angle of the swashplate is determined from the linear translation of the control piston. Preferably, a sensor arrangement according to the invention is used.

Another aspect of the invention refers to a controller for controlling the actuation of a control piston of a variable displacement hydraulic pump, the control piston being operable to control an angle of a swashplate relative to the pump, wherein an actual swashplate angle is determined with a sensor arrangement according to the invention and/or by a method according to the invention. Preferably, the control piston is actuated by a proportional valve.

Yet another aspect of the invention refers to a variable displacement hydraulic pump, wherein a control piston is operable to control an angle of the swashplate relative to the pump, comprising a controller according to the invention.

More advantages and details will become apparent from the embodiment according to the invention which will be described with respect to the attached drawings.

Referring to the drawings, in FIG. 1, a sectional view in a X-Y plane of a variable displacement hydraulic pump 10 with a rotative sensor S according to the state of the art is depicted. The sensor arrangement according to the invention will be described with respect to FIG. 2, wherein an identical variable displacement hydraulic pump 10 is depicted in a sectional view in a Y-Z plane. The following description refers to both the method and apparatus according to the invention.

With particular reference to FIGS. 1 and 2, the variable displacement hydraulic pump 10, hereinafter also referred to as pump 10, is preferably an axial piston swashplate hydraulic pump 10 having a plurality of pistons 11, e.g., seven or nine, located in a circular array within a cylinder block 8. Preferably, the pistons 11 are spaced at equal intervals about a shaft 6, located at a longitudinal center axis of the block 8. The cylinder block 8 is compressed tightly against a valve plate 20 by means of a cylinder block spring 14. The valve plate includes an intake port 24 and a discharge port 26. Each piston 11 is connected to a slipper 12, preferably by means of a ball and socket joint 23. Each slipper 12 is maintained in contact with a swashplate 1. The swashplate 1 is inclinedly mounted to the pump 10, the angle of inclination being controllably adjustable. With continued reference to FIGS. 1 and 2, operation of the pump 10 is illustrated. The cylinder block 8 rotates at a constant angular velocity. As a result, each piston 11 periodically passes over each of the intake and discharge ports 24, 26 of the valve plate 20. The angle of inclination of the swashplate 1 causes the pistons 11 to undergo an oscillatory displacement in and out of the cylinder block 8, thus drawing hydraulic fluid into the intake port 24, which is a low pressure port, and out of the discharge port 26, which is a high pressure port. In the preferred embodiment, the angle of inclination α of the swashplate 1 inclines about a swashplate pivot axis in X-direction and is controlled by a control piston 2. The control piston 2 operates to increase the angle of inclination of the swashplate 1, thus increasing the stroke of the pump 10. The pump 10 provides pressurized hydraulic fluid to the discharge port 26 of the valve plate 20.

Referring now to FIG. 1, according to the state of the art, means for determining an actual swashplate angle is adapted to determine the angle of the swashplate 1. In FIG. 1, the means for determining an actual swashplate angle includes a swashplate angle sensor S, which in the shown example is a resolver connected to the swashplate 1.

A sensor arrangement according to the invention is now described with respect to FIG. 2. The sensor arrangement comprises the control piston 2 operable to control the angle of the swashplate 1 relative to the pump 10, a position marker 3 arranged on the control piston 2 and a sensor 4 arranged along the control piston 2 to detect a movement of the position marker 3. In the depicted embodiment, the sensor 4 is aligned in parallel to the centre axis of the control piston 2. Alternatively, the sensor 4 could be arranged coaxially, inside the control piston 2. By using such a sensor arrangement, all clearances in the control loop are advantageously eliminated. This allows for a much more stable pump control compared to the existing design. Further, a contactless sensor arrangement may advantageously be applied, thus providing a completely wear-free design.

The preferred embodiment of the sensor arrangement of FIG. 2 comprises a linear magnetostrictive position sensor 4 arranged generally parallel to a direction of movement of the control piston 2, wherein the position marker 3 is a magnet 3. Magnetostriction is a property of ferromagnetic materials such as iron, nickel, and cobalt. When placed in a magnetic field, these materials change size and/or shape. Interaction of an external magnetic field with the magnetic domains causes the magnetostrictive effect. The ferromagnetic materials used in magnetostrictive position sensors 4 are transition metals such as iron, nickel, and cobalt. Vice versa, applying stress to a magnetostrictive material changes its magnetic properties, e.g., magnetic permeability. This is called the Villari effect. Magnetostriction and the Villari effect are preferably both used in producing the magnetostrictive position sensor 4, comprising a wire 5 (cf. FIG. 3) made of a magnetostrictive material. The wire 5 is enclosed within a protective cover 7 and is attached to the stationary part of the pump 10.

Details of the sensor arrangement are now described with reference to the schematic illustration of FIG. 3. An important characteristic of the wire 5 made of a magnetostrictive material is the Wiedemann effect. When an axial magnetic field is applied by the position marker magnet 3 to the magnetostrictive wire 5, and a current is passed through the wire 5, a twisting occurs at the location of the axial magnetic field. The twisting is caused by interaction of the axial magnetic field of magnet 3, usually a permanent magnet, with the magnetic field along the magnetostrictive wire 5, which is present due to the current in the wire 5. The current is applied, e.g., as a short-duration pulse of one or two us, and the resulting mechanical twisting travels along the wire 5 as an ultrasonic wave. The magnetostrictive wire 5 is therefore also called waveguide 5. The wave travels at the speed of sound in the waveguide material, about 3000 m/s. In operation of a magnetostrictive position sensor 4, the interaction of the current pulse with the position magnet 3 generates a strain pulse that travels down the waveguide 5 and is detected by a pickup element 15. The axial magnetic field is provided by the posi-
tion magnet 3. The position magnet 3 is attached to the control piston 2. The protective cover 7 enclosing the waveguide wire 5 is not illustrated. The location of the position magnet 3 is determined by first applying a current pulse to the waveguide 5. The current pulse causes a sonic wave to be generated at the location of the position magnet 3. The sonic wave travels along the waveguide 5 until it is detected by the pickup 15. The elapsed time then represents the distance between the position magnet 3 and the pickup 15. In order to avoid an interfering signal from waves travelling in a direction away from the pickup 15, their energy is absorbed by a damping device 16. The pickup 15 makes use of the Villari effect. A small piece of magnetostrictive material tape 17 is welded to the waveguide 5 near one end of the waveguide 5. This tape 17 passes through a coil 18 and is magnetized by a small permanent bias magnet 19. When a sonic wave propagates down the waveguide 5 and then down the tape 17, the stress induced by the wave causes a wave of changed permeability in the tape 17. This in turn causes a change in the tape magnetic flux density, and thus a voltage output pulse is produced from the coil 18, due to the Faraday effect. The voltage pulse is detected at the coil contacts 21, 22 by an electronic circuitry (not depicted) and conditioned into a desired output.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. It will be understood that changes and modifications may be made by those of ordinary skill within the scope of the following claims. In particular, the present invention covers further embodiments with any combination of features from different embodiments described above and below. Additionally, statements made herein characterizing the invention refer to an embodiment of the invention and not necessarily all embodiments.

The terms used in the claims should be construed to have the broadest reasonable interpretation consistent with the foregoing description. For example, the use of the article “a” or “the” in introducing an element should not be interpreted as being exclusive of a plurality of elements. Likewise, the recitation of “or” should be interpreted as being inclusive, such that the recitation of “A or B” is not exclusive of “A and B,” unless it is clear from the context or the foregoing description that only one of A and B is intended. Further, the recitation of “at least one of A, B, and C” should be interpreted as one or more of a group of elements consisting of A, B, and C, and should not be interpreted as requiring at least one of each of the listed elements A, B, and C, regardless of whether A, B, and C are related as categories or otherwise. Moreover, the recitation of “A, B, and/or C” or “at least one of A, B, or C” should be interpreted as including any singular entity from the listed elements, e.g., A, any subset from the listed elements, e.g., A and B, or the entire list of elements A, B, and C.

REFERENCE NUMERALS

1 swashplate
2 control piston
3 position marker, position magnet
4 sensor
5 wire, waveguide
6 shaft
7 protective cover
8 cylinder block
9 variable displacement hydraulic pump
10 11 piston
12 slipper
13 cylinder block spring
14 pickup
15 permanent bias magnet
16 damping element
17 tape
18 coil
19 valve plate
20 coil contacts
21, 22 coil joint
23 intake port
24 discharge port
25 resolver

1. A sensor arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, the arrangement comprising:

   A control piston operable to control an angle of the swashplate relative to the variable displacement pump;

   A position marker arranged on the control piston; and

   A sensor arranged along the control piston to detect a movement of the position marker.

2. The arrangement of claim 1, wherein the sensor is adapted to detect the movement of the position marker in a contactless manner.

3. The arrangement of claim 1, wherein the sensor is arranged generally parallel or coaxially to a direction of movement of the control piston.

4. The arrangement of claim 1, wherein the sensor is a linear magnetostrictive position sensor, and wherein the position marker is a magnet.

5. A measurement method for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, wherein a control piston is operable to control an angle of the swashplate relative to the pump, the method comprising:

   Detecting a position of a position marker arranged on the control piston by a sensor arranged along the control piston; and

   Determining a linear translation of the control piston from a shift of the position marker relative to the sensor.

6. The method of claim 5, wherein comprising:

   Determining the actual swashplate angle of the swashplate from the linear translation of the control piston.

7. The method of claim 5, wherein carried out using a sensor arrangement arrangement for determining an actual swashplate angle of a swashplate pivotally attached to a variable displacement hydraulic pump, the arrangement comprising:

   A control piston operable to control an angle of the swashplate relative to the variable displacement pump;

   A position marker arranged on the control piston; and

   A sensor arranged along the control piston to detect a movement of the position marker.

8. A controller for controlling the actuation of a control piston of a variable displacement hydraulic pump, the control piston being operable to control an angle of a swashplate relative to the pump, wherein an actual swashplate angle is determined with Hall the sensor arrangement of claim 1.

9. The controller of claim 8, wherein the control piston is actuated by a proportional valve.

10. A variable displacement hydraulic pump comprising:

   The controller of claim 8, wherein the control piston is operable to control an angle of the swashplate relative to the pump.
11. The arrangement of claim 1, wherein the sensor is arranged generally coaxially to a direction of movement of the control piston.

12. The arrangement of claim 1, wherein the sensor includes a linear magnetostrictive position sensor.

13. The arrangement of claim 1, wherein the position marker includes a magnet.

14. The arrangement of claim 1, wherein the sensor includes a linear magnetostrictive position sensor, and wherein the position marker includes a magnet.

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